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OUTPUT/INPUT DIFFERENCES AMONG NONPREGNANT, LACTATING *BOS INDICUS-BOS TAURUS* AND *BOS TAURUS-BOS TAURUS* F_1 CROSS COWS[1]

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ABSTRACT

Nonpregnant F_1 crossbred cows, progeny of either Hereford (H) or Angus (A) dams and sired by Brahman (Bm), Sahiwal (Sw), Pinzgauer (Pz), H, or A sires, were fed to maintain initial weight while rearing Charolais (C)-sired progeny for a period of 126 d in drylot commencing at about 48 d postpartum. Cow-calf pairs were assigned to equalize cow age, calf sex, and breed of cow's dam among three replicate pens of approximately 12 pairs each. Cows and calves were weighed every 2 wk and feed intake was adjusted to minimize change in cow weight. Metabolizable energy (ME) consumption for zero cow weight change was estimated by regression. Milk production was estimated by weigh-suckle-weigh at 58, 85, 125, and 170 d of lactation. Calf gain (GAIN, kg) relative to cow weight (CWT_1, kg) was higher ($P < .01$) for calves from Bm-X (139.5/585) and Sw-X (132.2/534) than for calves from Pz-X (127.2/552) and HA-X (116.9/547) cows. Estimated mean daily production of milk was 7.40, 7.15, 7.28, and 6.37 kg for the Bm-X, Sw-X, Pz-X, and HA-X, respectively. Total cow ME intake (TME_{cow}) for breed groups ranked ($P < .05$) with cow size and milk production, and calf creep-feed intake (FME_{calf}) was inversely related to estimated milk intake. Proportion of total feed ME ($TME_{cow+calf}$) consumed by calves was higher ($P < .05$) for HA-X cows (18%) than for the others (14%). Total efficiency of calf gain in weight ($GAIN/TME_{cow+calf}$) was 11% greater ($P < .05$) for crossbred cows of *Bos indicus* × *Bos taurus* (Bm-X, Sw-X) than for *Bos taurus* × *Bos taurus* (Pz-X, HA-X) cows (35 vs 32 g/Mcal) in the 126-d lactation period.

Key Words: Beef Cattle, Breeds, Crossbreeding, Efficiency, Lactation

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Introduction

Matching germ plasm to resources through designed crossbreeding programs can contribute to optimum beef production efficiency (Dickerson, 1982; Cundiff et al., 1986). However, this approach requires considerable knowledge about genetic diversity among breeds in components of performance. This need, coupled with the importation of a vast array of cattle germ plasm into the United States from continental Europe in the late 1960s and early 1970s, gave impetus to establishment of the Germ Plasm Evaluation (GPE) program at the Roman L. Hruska United States Meat Animal Research Center (RLHUSMARC). In Cycles I and II of the GPE program, increases in cow output associated with higher breed potential for growth rate and milk production were offset by equivalent or greater increases in feed requirements for maintenance and lactation (Cundiff et al., 1983; Jenkins and Ferrell, 1983; Ferrell

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and Jenkins, 1984). Output of calf weaned per cow in the breeding herd has been high for Brahman-cross females, moderately high for Sahiwal and Pinzgauer crosses, and low for Hereford-Angus crosses relative to other F_1 females in Cycle III of the program (Cundiff et al., 1986).

Information is needed for the further evaluation of production efficiency for *Bos indicus* relative to *Bos taurus* sources of germ plasm. The present study was conducted to compare 1) feed requirements for maintenance and lactation and 2) production efficiency measured as progeny weight gain/feed consumed by cow and calf, during 18 wk of lactation for Brahman-, Sahiwal-, Pinzgauer-, Hereford-, and Angus-sired cows from Hereford and Angus dams while they reared Charolais-sired calves.

Experimental Procedures

Experimental Plan. This study was conducted at the RLHUSMARC, Clay Center, NE during the summer of 1987. Cows involved were F_1 crosses from Cycle III, Phase 2 (III-2) of the GPE program, progeny of either Hereford (H) or Angus (A) dams, by sires representing Brahman (Bm), Sahiwal (Sw), Pinzgauer (Pz), and H, or A breeds (Gregory et al., 1979a,b). Most of these cows were born in 1975 and 1976, but a few Pz-X cows were born in 1980. The terminal years for this phase of the GPE program were 1986 and 1987. For the 1987 calving season, all III-2 cows were bred by natural service to Charolais (C) bulls.

The intent in this study was to use 12 cow-calf pairs in each of three replicate pens for each of the four F_1 breed crosses. However, only 11 cows were available for each of the three Pz-X replicates and for one each of the Bm-X and HA replicates. Early in the study, one additional cow was lost from each of two HA-X and one Bm-X pens, reducing the total number of pairs studied to 136.

Cows were maintained on cool-season (brome) pastures early in the production year followed by warm-season (mixture of switch and bluestem) pastures late in the breeding season and were supplemented with hay during the winter months before the experimental period. Calving was in late March through mid-May and all male calves were castrated shortly after birth. Cow-calf pairs were allowed access to corn silage for several days before they were moved to the experimental feedlot on May 20th for a 6-d warm-up period on drylot feed.

Cow-calf pairs were assigned to replicate feedlot pens in an order that attempted to balance age of cow, sex of calf, age of calf, and breed of cow's dam among all pens (Table 1). There were twice as many cows from A as

TABLE 1. NUMBER OF COW-CALF PAIRS BY COW BREED CROSS AND REPLICATE, BREED OF COW'S DAM, COW BIRTH YEAR, AND CALF SEX, WITH MEAN CALF BIRTH DATE IN 1987

Breed-X/ replicate[b]	Breed of cow's dam		Cow birth year			Calf sex		Mean calf birth date[a]
	Hereford	Angus	1975	1976	1980	Steer	Heifer	
HA-I	4	8	10	2	0	7	5	96.3
HA-II	3	7	6	4	0	6	4	98.6
HA-III	4	7	8	2	1	5	6	98.6
Pz-I	4	7	7	1	3	5	6	96.7
Pz-II	4	7	7	3	1	7	4	94.9
Pz-III	4	7	6	4	1	4	7	101.6
Bm-I	4	8	7	5	0	7	5	94.8
Bm-II	4	8	6	6	0	5	7	98.5
Bm-III	3	7	7	3	0	6	4	97.7
Sw-I	4	8	6	6	0	6	6	93.0
Sw-II	4	8	3	9	0	10	2	96.5
Sw-III	4	8	2	10	0	8	4	98.9
Totals	46	90	75	55	6	76	60	

[a]Julian calendar days.

[b]HA = Hereford × Angus crosses, Pz-X, Bm-X and Sw-X are Pinzgauer-, Brahman-, and Sahiwal-sired crosses from Hereford and Angus dams.

TABLE 2. COMPOSITION OF DIET

Ingredient	Percentage[a]
Corn silage	77.30
Ground brome hay	18.80
Soybean meal	2.93
Limestone	.62
Dicalcium phosphate	.31
Vitamins ADE	.02
Aureomycin	.01
Trace mineral premix	ad libitum

[a]Expressed as percentage of DM. Diet contained 2.44 Mcal/g of DM, approximately 40.5% DM and 10.5% CP.

from H dams, but the ratio was relatively constant among pens and breeds. There were more male calves than female calves in two pens from Sw-X cows. The majority of HA-X and Pz-X cows were born in 1975, and none of the Bm-X or Sw-X cows was born in 1980. The range in mean age of calf among pens was only 9 d.

In drylot, cows were fed a mixed ration of corn silage, protein supplement, and ground brome hay (Table 2) for 126 d. Energy (ME) content of the ration was 2.44 Mcal/kg of DM, as calculated from NRC (1984). Calves were allowed creep access to whole oats and were assumed to consume negligible amounts of cow feed from feed bunks, which had been modified to avoid calf access.

The intent of the study was to estimate cow input requirements for maintenance and milk production with no gain in cow weight during 18 wk of lactation. This involved monitoring cow weight changes every 2 wk. Pen feed intake was adjusted every 2 wk to minimize pen average weight change over the course of the feeding period. Dry matter of the total diet also was analyzed at 2-wk intervals and used in calculating feed intakes. The DM content of the diet never varied more than 2 to 3%.

At the beginning and end of the trial, data also were collected for the cow's backfat thickness (FAT, cm, estimated by probing depth from skin surface to the longissimus muscle with a 16-gauge needle at 7 to 8 cm from the midline over the 12th rib), hip height (HIP, cm, measured at the hooks), and visual condition score (CS, on a scale of 1 = emaciated to 10 = extremely obese).

Total 126-d calf consumption of creep feed also was estimated for each pen from regression of cumulative consumption measured every 2 wk on cumulative days. Calf growth was monitored from weights taken at the same intervals at which cow weights were measured.

Weigh-suckle-weigh procedures were used to estimate milk production. In the preliminary 1986 experiment, milk production was estimated for 44 other cow-calf pairs of the same III-2 cows at six sampling dates corresponding to average days in lactation of 20, 35, 50, 75, 105, and 135. Cows were separated from calves for 12 h overnight; calves were weighed, allowed to nurse for 15 to 20 min or until they were observed to be finished, and then reweighed. The change in weight during suckling was an estimate of 12-h milk yield, which was doubled to estimate daily (24 h) yield. In the primary 1987 project, sampling was done only at approximately 58, 85, 125, and 160 d of lactation, with separation periods of 15 h rather than 12 h. Each pen of 12 cows was divided into two groups of six each, to facilitate quicker and easier handling of the larger numbers of animals in 1987.

Statistical Analysis. To estimate the ME required for maintenance and lactation, average daily change in cow weight (CDG) was regressed on mean daily ME intake (DME) and cow metabolic body size (CMWT) for each 14-d period of a pen according to the following model of Ferrell and Jenkins (1984):

$$CDG_i = b_1 (DME_i) + b_2 (CMWT_i) + e_i, \quad [1]$$

where CDG_i = pen mean average daily change in weight (kg/d) for the i^{th} 14-d period, DME_i = mean daily metabolizable energy intake (Mcal/d) per cow for the i^{th} 14-d period, $CMWT_i$ = mean cow metabolic body size for the i^{th} period calculated as (mean cow weight)$^{.75}$, b_1, b_2 = partial regression coefficients on DME and CMBS, respectively, and e_i = random error.

Daily ME intake per cow for maintenance and lactation (DME_{zero}) was then calculated from the regression equations for each pen as the point at which CDG equaled zero as follows:

$$DME_{zero} = -(b_2 {*} CWT_1{}^{.75})/b_1, \quad [2]$$

where CWT_1 = initial cow weight.

Several values were computed to describe weight and condition changes of the cows. Changes in fat thickness (ΔFAT), condition score (ΔCS), and hip height (ΔHIP) were calculated between the initial (I) and final (F) points of the experimental period. Cow weight change over the total 126-d period was assessed as the final minus initial cow weight (ΔCWT_1), and as mean minus initial cow weight (ΔCWT_2).

Calf growth was described by gain over the 126-d period, both as total (GAIN) and per day (PDG).

Milk production was estimated as proposed by Jenkins and Ferrell (1984), fitting lactation curves with the following model:

$$Y(n) = n/ae^{kn}, \quad [3]$$

where Y(n) = daily milk yield (kg) on the n^{th} day of lactation, n = day of lactation, a,k = curve parameters, and e = natural logarithm.

This equation was made linear by dividing by n and taking the logarithm of both sides of the equation, which allowed estimation of curve parameters a and k. Large sampling errors were experienced in fitting curves for individual pens. Therefore, curves were fitted on a pooled, within-breed basis from the combined 1986 and 1987 data collection periods to increase numbers and because of the additional points of the lactation represented in 1986 data. Day of peak lactation (PPK) was estimated as 1/k, yield at day of peak lactation (YPK) as 1/(ake), total milk yield during the feeding period as the mathematical integration of the curve over the corresponding days of lactation (TMLK), average milk yield over the feeding period (XMLK) as TMLK divided by number of days in the period, and persistency of lactation (PER) as TMLK/YPK.

Calculation of efficiency involved estimated total consumption of feed ME by the cow (TME_{cow}), of creep feed by the calf (FME_{calf}), and the total feed ME consumption for cow and calf ($TME_{cow+calf}$). The TME_{cow} was computed as DME_{zero} for each pen multiplied by number of days on feed, FME_{calf} was the estimated pen mean of creep feed ME per calf, and their sum was $TME_{cow+calf}$. Pen mean ME intake per calf from milk alone (PMLKME) was estimated by assuming .75 Mcal of ME per kilogram of milk (Petit and Micol, 1981) consumed by the calf over the feeding period. Alternative efficiencies were then calculated for cows (CEFF) as calf gain (GAIN) divided by TME_{cow}, for calves (PEFF) as GAIN divided by the sum of FME_{calf} and PMLKME, and for total (TEFF) as GAIN divided by $TME_{cow+calf}$ feed intake, independent of estimated milk intake.

All variables measured and calculated on a pen mean basis were analyzed in a one-way ANOVA to detect differences among breed-cross groups, using among replicates within breed as the error term. Three linear contrasts also were tested, allowing comparisons of *Bos indicus* × *Bos taurus* (Bm-X and Sw-X) vs *Bos taurus* × *Bos taurus* (HA-X and Pz-X), Bm-X vs Sw-X, and Pz-X vs HA breed crosses. Tests for differences among breed-cross means were made using Duncan's multiple range test (Steel and Torrie, 1980).

Results and Discussion

All abbreviations for variables used in tables and text are summarized in Table 3. The tests of significance from ANOVA shown in Table 4 for major measurement variables will be used in the subsequent discussion of results.

Cow Weight and Condition. Breed-cross means for cow weight, measurement, and condition variables (Table 5) indicate that indicate that initial cow weight (CWT_1) was about 7% greater ($P < .01$) for Bm-X than for Sw-X or the mean of HH-X and Pz-X cows. Relative cow weights for these crosses changed very little during the entire lactation period.

Cow weight changes over the 126-d feeding period (ΔCWT_1) were positive and similar for all four crosses, ranging from 4 kg for HA-X and Bm-X to 8 kg for Sw-X and 9 kg for Pz-X. However, the pattern of weight change evaluated as average weight less initial weight (ΔCWT_2) was significantly ($P < .05$) greater for Pz-X (4.5 kg) than for Bm-X (–3.1 kg); HA-X (1.8 kg) and Sw-X (.8 kg) were intermediate. Cows in all pens lost weight during the sixth and seventh 14-d periods, and regained weight during the remaining three periods.

Measures of body condition also indicated some gain in cow weight during the feeding period. Fat depth measures (ΔFAT) increased similarly for all breed crosses by .06 to .16 cm over the 126-d period but were significant only for Pz-X (.16 cm) and HA-X (.13 cm). Changes in fat measurements corresponded to average changes in body weight (ΔCWT_2) somewhat more closely than to total changes in weight (ΔCWT_1). Cows of all breed groups were in relatively good condition at the beginning of the trial, but skin-plus-fat thickness (FAT) for the *Bos indicus* crosses was greater than that for the *Bos taurus* crosses ($P < .01$) by approximately .25 cm and was greater for the Sw-X than for the Bm-X ($P < .05$) by 14 cm. Condition scores also reflected these differences in fatness among crosses. Condition scores for all breed groups were 7 or higher at the initial measurement date (ICS), and subsequent increases (ΔCS) closely followed those for FAT.

Skeletal size, as measured by height over the hips (XHIP) was greater ($P < .01$) for Bm-X cows than for Sw-X, Pz-X, and HA-X cows and did not change over the 126-d period.

Progeny Characteristics. Means for progeny measurements are given by breed cross in Table 6. Because calves differed only in 1/4 of their breed inheritance (1/4 H or A, 1/2 C, and 1/4 sire breed), their performance was not expected to differ greatly.

Mean initial calf age (IPAGE) ranged only from 48 to 50 d among crosses. Mean birth weights (PWT_0) were about 16% heavier ($P < .01$) for calves from the British-cross Pz-X and HA-X than for calves from Bm-X and Sw-X cows. Calves from Sw-X dams also were smaller than those from Bm-X dams ($P < .01$).

TABLE 3. DEFINITIONS OF ABBREVIATIONS USED TO DESCRIBE DATA FOR PEN MEANS

Acronym	Definition
Breed-X	Refers to F_1 crosses for each of five sire breeds (H, A, Pz, Sw, and Bm) pooled over the two dam breeds (H or A)
CWT_i	Cow weight at the i^{th} 2-wk period (kg)
$CMWT_i$	Mean cow metabolic body weight $(CWT_i)^{.75}$ for the i^{th} 2-wk period
ΔCWT_1	Final CWT less initial CWT
ΔCWT_2	Mean CWT less initial CWT
IFAT	Initial on-test cow backfat thickness (cm)
FFAT	Final off-test cow backfat thickness (cm)
XFAT	Mean of IFAT and FFAT
ΔFAT	FFAT less IFAT
IHIP	Initial on-test cow hip height (cm)
FHIP	Final off-test cow hip height (cm)
XHIP	Mean of IHIP and FHIP
ICS	Initial on-test visual condition score (scale 1 to 10)
FCS	Final off-test visual condition score
XCS	Mean of ICS and FCS
ΔCS	FCS less ICS
a, k	Lactation curve parameters
XMLK	Mean *daily* milk production for the 126-d feeding period (kg/cow)
TMLK	Total lactation yield for the 126-d feeding period (kg)
DPK	Day of estimated peak lactation
YPK	Pen mean daily milk yield at peak lactation (kg/cow)
PER	Persistency of lactation (TMLK/YPK)
DME_i	Mean *daily* metabolizable energy intake (Mcal/cow) for the i^{th} 2-wk period
CDG_i	Mean *daily* weight change (kg/cow) for the i^{th} 2-wk period
DME_{zero}	Estimated mean *daily* metabolizable energy intake (Mcal/cow) for zero change in cow weight
PWT_0	Calf birth weight (kg)
PWT_i	Calf weight in the i^{th} 14-d period
PAGE	Calf age in days
IPAGE	Initial calf age
GAIN	Calf weight gain over the feeding period (kg)
PDG	Calf mean *daily* gain over the feeding period (kg)
TME_{cow}	Total metabolizable energy intake per cow for the entire feeding period for zero weight change
CEFF	GAIN divided by TME_{cow} (kg/Mcal)
FME_{calf}	Total metabolizable energy intake of creep feed per calf for the entire feeding period (Mcal)
PMLKME	Total metabolizable energy intake of calves from milk for the entire feeding period, assuming .75 Mcal ME/kg milk (Mcal)
PEFF	Calf gain divided by the sum of PMLKME and FME_{calf} (kg/Mcal)
$TME_{cow+calf}$	TME_{cow} plus FME_{calf}
TEFF	GAIN divided by $TME_{cow+calf}$ (kg/Mcal)
$\%ME_{cow}$	TME_{cow} as a percentage of $TME_{cow+calf}$
$\%ME_{calf}$	$100 - \%\ ME_{cow}$

This observation is in agreement with the general finding (Franke, 1980; Turner, 1980; Cundiff et al., 1986) that *Bos indicus-Bos taurus* dams have a strong maternal influence for relatively lighter calf birth weights. Although initial calf weight (PWT_1) was about 14% heavier ($P < .01$) for the Pz-X than for the other three breed groups, the higher rate of growth (PDG) for calves from Bm-X and Sw-X dams allowed them to become as heavy in final weight (**PWT_{10}**) as the Pz-X and heavier than the HA-X calves ($P < .01$). Deviations from HA-X calves for PWT_1, PDG, and PWT_{10} were –1.2, 19.5, and 10.8% for Bm-X calves, –4.4, 12.9, and 5.9% for Sw-X calves; and 12.1, 8.6, and 10.2% for Pz-X calves, respectively.

Differences between initial (PWT_1) and birth (PWT_0) weights indicated that calves from Pz-X, Bm-X, and Sw-X dams were similarly higher ($P < .01$) in their early relative rates of growth than calves from HA-X dams (see Table 6). Calf growth during the suckling period (GAIN and PDG) was essentially linear, with the ranking of dam breed groups in the order of Bm-X ≥ Sw-X ≥ Pz-X ≥ HA-X ($P < .01$). These patterns of growth seemed to reflect levels and persistency of lactation of the cow breed group (Figure 1).

Milk Production. Estimated lactation curve parameters and associated milk production levels from the pooled analysis over the 2 yr are given in Table 7, with lactation curves depicted graphically in Figure 1. The most striking differences in these curves were between the Pz-X and other three breed groups. Over the 126-d lactation period in the 1987 data, the Bm-X group had highest estimated total milk, followed closely by the Pz-X and Sw-X groups, and the HA-X cows

TABLE 4. *F*-STATISTICS[a], LEVELS OF SIGNIFICANCE[b], AND ERROR MEAN SQUARES OF MEASUREMENTS

	Source of variation				
Dependent variable[c]	Breed[d]	*Bos indicus* vs *Bos taurus*[e]	Sw-X vs Bm-X[f]	Pz-X vs HA-X[g]	Error[h]
CWT_1, kg	4.61*	1.02	12.64**	.16	314.5
CWT_{10}, kg	4.48*	.94	11.94**	.56	291.5
ΔCWT_1, kg	.62	.06	.59	1.19	27.8
ΔCWT_2, kg	3.74†	6.98*	2.83	1.41	7.9
XFAT, cm	16.48***	41.02***	7.82*	.59	.004
XHIP, cm	8.41**	12.41**	8.08*	4.74†	4.4
XCS	3.75†	9.98**	.24	1.02	.03
PAGE, d	.28	.67	.17	.00	6.6
PWT^0, kg	38.64***	95.79***	18.08**	2.06	1.1
PWT^1, kg	4.68*	6.93*	.44	6.65*	23.1
PWT^{10}, kg	9.35**	4.01†	4.56†	19.48**	32.1
GAIN or PADG, kg	8.05**	17.08**	2.35	4.71†	33.8
DME_{zero} or TME_{cow}, Mcal/d	10.61**	2.82	10.30*	18.72**	.8 and 12201
FME_{calf}, Mcal	1.71	4.11†	.04	.98	5342.4
$TME_{cow+calf}$, Mcal	8.21**	.12	10.11*	14.40**	11426.9
$\%ME_{cow}$ or $\%ME_{calf}$	3.40†	5.19*	.03	4.19†	3.1
PEFF, kg/Mcal	4.23*	10.83*	.65	1.22	.00005
CEFF, kg/Mcal	1.33	3.25†	.35	.40	.000008
TEFF, kg/Mcal	2.50	7.37*	.12	.00	.000005

[a]*F*-statistic computed as (mean square (effect))/(mean square error).

[b]Significance denoted as ***$P < .001$, **$P < .01$, *$P < .05$ and †att;ip; < .10.

[c]See Table 3 for definition of abbreviations.

[d]Effect of breed cross, with 3 df.

[e]Linear contrast of Bm-X and Sw-X vs Pz-X and HA-X crosses, with 1 df.

[f]Linear contrast of Sw-X vs Bm-X, with 1 df.

[g]Linear contrast of Pz-X vs HA-X, with 1 df.

[h]Error mean square with 8 df.

TABLE 5. MEANS OF COW WEIGHTS, MEASUREMENTS, AND CONDITION SCORES BY BREED CROSS

	Breed cross				
Variable[a]	HA-X	Bm-X	Sw-X	Pz-X	SE[b]
CTW_1, kg	546.5[d]	585.4[c]	533.9[d]	552.2[cd]	10.2
CWT_2, kg	549.7[cd]	577.5[c]	525.2[d]	550.4[cd]	12.1
CWT_3, kg	553.4[cd]	584.9[c]	540.0[d]	551.8[cd]	11.3
CWT_4, kg	553.2[cd]	584.1[c]	534.6[d]	560.5[cd]	11.4
CWT_5, kg	552.6[d]	588.1[c]	540.0[d]	563.6[cd]	9.1
CWT_6, kg	548.9[cd]	583.3[c]	537.2[d]	557.8[cd]	10.1
CWT_7, kg	535.8[cd]	567.6[c]	526.7[d]	542.4[cd]	9.7
CWT_8, kg	541.4[d]	577.6[c]	534.4[d]	560.1[cd]	8.3
CWT_9, kg	550.4[de]	585.4[c]	534.8[e]	567.0[cd]	8.0
CWT_{10}, kg	550.7[d]	589.6[c]	541.4[d]	561.1[cd]	9.9
ΔCWT_1, kg	4.26[c]	4.19[c]	7.50[c]	8.96[c]	3.1
ΔCWT_2, kg	1.80[cd]	−3.06[d]	.80[cd]	4.53[c]	1.6
IFAT, cm	.98[e]	1.18[d]	1.32[c]	1.00[e]	.04
FFAT, cm	1.11[d]	1.25[cd]	1.38[c]	1.16[d]	.04
ΔFAT, cm	.13[c]	.07[c]	.06[c]	.16[c]	.04
IHIP, cm	126.0[d]	134.9[c]	130.0[d]	129.8[d]	1.29
FHIP, cm	125.9[d]	134.1[c]	129.3[d]	129.5[d]	1.13
ICS	7.18[cd]	7.40[c]	7.47[c]	6.97[d]	.12
FCS	7.28[c]	7.47[c]	7.53[c]	7.21[c]	.12
ΔCS	.11[c]	.07[c]	.06[c]	.24[e]	.14

[a]See Table 3 for definition of abbreviations.

[b]Standard error of breed-cross means.

[c,d,e]Means within a row with different superscripts differ ($P < .05$).

produced about 12% less. The corresponding mean daily milk productions were 7.4, 7.3, 7.2, and 6.4 kg/d.

These estimates are lower than those previously reported (Cundiff et al., 1986) for the Bm-X and Sw-X groups as 3- and 4-yr-olds (8.2 and 7.8 kg/d, respectively) but are comparable to those reported for Pz-X (7.2 kg/d) and higher than those reported for HA-X (5.4 kg/d). The earlier estimates by Cundiff et al. (1986) were averages of three 12-h estimates taken by weigh-suckle-weigh procedures at 130, 160, and 190 d postpartum when these cows were grazing improved pastures. These differences between the milk intake estimates in this study and those for the same breed groups at younger cow ages, coupled with the previously discussed superior calf growth and lower creep-feed intake (Table 8) for the two *Bos indicus* crosses, could lead to the conclusion that the levels of daily milk production for the *Bos indicus* crosses were underestimated in

TABLE 6. MEANS FOR CALF PERFORMANCE BY BREED CROSS

	Breed cross				
Variable[a]	HA-X	Bm-X	Sw-X	Pz-X	SE[b]
PAGE, d	48.2[c]	49.0[c]	49.9[c]	48.3[c]	1.5
PWT_0, kg	41.2[c]	37.7[d]	34.0[e]	42.4[c]	.6
PWT_1, kg	83.5[d]	82.5[d]	79.9[d]	93.6[c]	2.8
PWT_{10}, kg	200.3[d]	222.0[c]	212.2[c]	220.8[c]	3.3
GAIN, kg	116.9[e]	139.5[c]	132.2[cd]	127.2[de]	3.4
PDG, kg	.93[e]	1.11[c]	1.05[cd]	1.01[de]	.03

[a]See Table 3 for definition of abbreviations.

[b]Standard error of breed-cross means.

[c,d,e]Means within a row with different superscripts differ ($P < .05$).

TABLE 7. ESTIMATED 126-DAY MILK PRODUCTION AND LACTATION CURVE PARAMETERS BY BREED CROSS

Parameter Estimate[a]	Breed cross			
	HA-X	Bm-X	Sw-X	Pz-X
a	2.687	2.811	2.832	1.897
k	.0166	.0147	.0149	.0187
DPK, d	60.3	68.0	67.0	53.5
YPK, kg	8.26	8.89	8.71	10.38
TMLK[b], kg	802.3	928.4	897.9	917.5
XMLK, kg	6.37	7.40	7.15	7.28
PER (TMLK/YPK)	97.2	104.3	103.1	88.4

[a]See Table 3 for definition of abbreviations.

[b]Total lactation yield for 126-d period corresponding to 1987 feeding period.

the 1986–87 experiments. The argument that estimates of milk production from primarily 11- and 12-yr-old females might be expected to be lower than those from comparable animals in earlier lactations is not supported by the data for the HA-X and Pz-X groups. Additionally, the estimates of Cundiff et al. (1986) may have differed from those in this study because of interactions involving breed-group or behavioral, nutritional (drylot ration vs pasture), and sampling size considerations. When milk production estimates are used in predicting input costs, actual levels of milk intake are only important as they influence amounts of calf creep feed consumed.

Feed Energy Inputs. Mean feed energy inputs of cows and calves by breed cross are presented in Table 8. Actual mean DME was higher ($P < .01$) for the Bm-X and Px-X than for Sw-X or HA-X cows, probably because of larger cow size and(or) higher milk production. The smaller Sw-X cows were intermediate because of higher milk production and the HA-X were lowest, as expected from their small

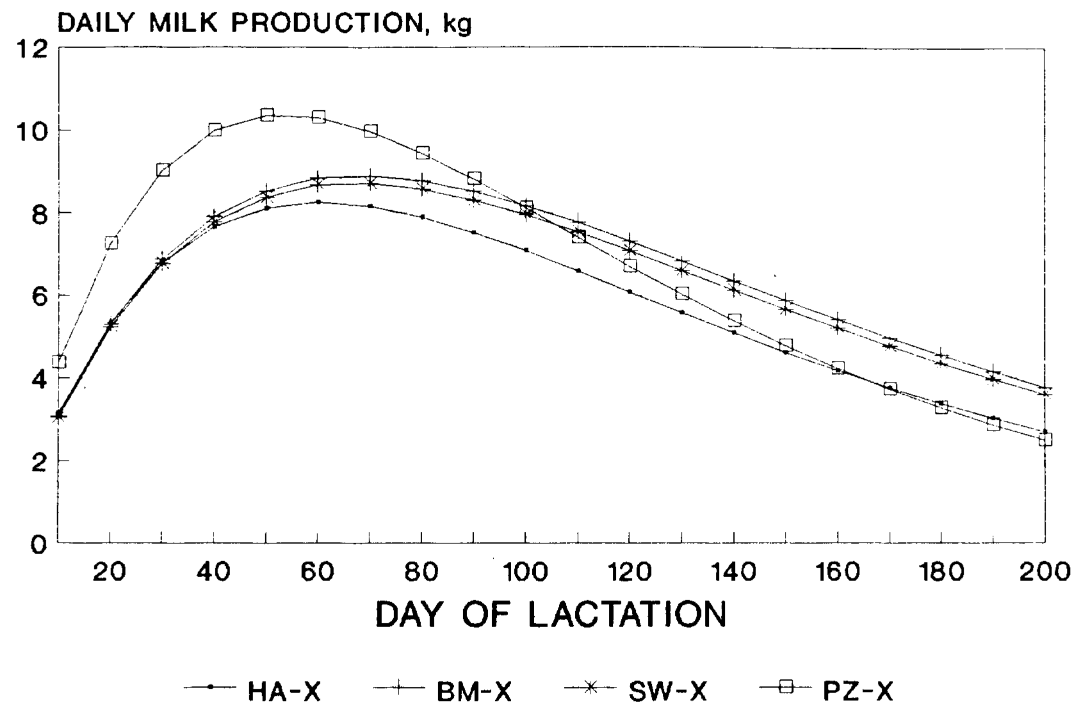

Figure 1. Lactation curves by breed cross.

TABLE 8. MEAN FEED ENERGY INPUTS BY BREED CROSS

Variable[a]	Breed cross				SE[b]
	HA-X	Bm-X	Sw-X	Pz-X	
DME, Mcal/cow	24.82[e]	27.66[c]	26.47[d]	27.74[c]	.3
DME_{zero}, Mcal/cow	24.15[d]	27.70[c]	25.40[d]	27.25[c]	.5
TME_{cow}, Mcal/cow	3,043.3[d]	3,490.2[c]	3,200.8[d]	3,433.5[c]	63.8
FME_{calf}, Mcal/calf	664.5[c]	543.5[c]	555.3[c]	605.5[c]	42.2
$TME_{cow+calf}$, Mcal/pair	3,707.8[d]	4,033.7[c]	3,756.2[d]	4,039.0[c]	61.8
$\%ME_{cow}$, %	82.1[d]	86.5[c]	85.2[cd]	85.0[cd]	1.0
$\%ME_{calf}$, %	17.9[d]	13.5[c]	14.8[cd]	15.0[cd]	1.0

[a]See Table 3 for definition of abbreviations.

[b]Standard error of breed-cross means.

[c,d,e]Means within a row with different superscripts differ ($P < .05$).

size and low milk yield. Because of the relatively minor changes in cow weight, adjusting ME intakes for weight changes over the feeding period (DME_{zero}) caused little change in the differences among groups. The corresponding deviations from HA-X in total ME intake per cow for the 126-d feeding period (TME_{cow}) were 15% for Bm-X, 13% for Pz-X, and 5% for Sw-X cows.

The higher mean calf creep feed consumption (FME_{calf}) for HA-X (20%) and Pz-X (10%) than for Bm-X and Sw-X cows only approached significance ($P < .10$). Except for the Pz-X group, these levels of creep consumption were inversely related to level of milk consumption. Calves from Bm-X and Sw-X cows consumed roughly 9% less creep feed than calves from Pz-X cows, even though milk production was similar and calf weight gain somewhat greater. A possible partial explanation may be that the Pz-X cows tended to produce more milk early in lactation and less later when the calves were larger and their nutrient requirements for maintenance and growth were higher (Figure 1). The possible underestimation of milk intake of calves from Bm-X and Sw-X cows discussed earlier also could help account for the low creep feed consumption by these calves.

The partitioning of feed energy utilization into cow and calf components is shown in Table 8. The larger FME_{calf} and lower TME_{cow} for the HA-X group made them 4% lower ($P < .05$) in $\%ME_{cow}$ than the Bm-X group; the Sw-X and Pz-X crosses were intermediate. In one replicate of Pz-X, calves consumed less ME as a percentage of total feed use than those in the other two replicates of Pz-X or those in any other pen of the trial, as expected from the considerably higher level of milk production for this one Pz-X replicate. These results are comparable to those of Cundiff et al. (1983) in a similar study of 138 d of lactation with Cycle II-2 GPE cows, in which the range in $\%ME_{cow}$ was 81 to 85%. Calves in this 1983 study consumed the

TABLE 9. MEAN EFFICIENCY VALUES BY BREED CROSS

Variable[a]	Breed cross				SE[b]
	HA-X	Bm-X	Sw-X	Pz-X	
PEFF, g/Mcal	91.3[d]	110.7[c]	105.9[c]	97.8[cd]	4
	(100)	(122)	(116)	(107)	
CEFF, g/Mcal	38.5[c]	40.0[c]	41.3[c]	37.1[c]	2
	(100)	(104)	(107)	(96)	
TEFF, g/Mcal	31.6[c]	34.6[d]	35.2[d]	31.5[c]	1
	(100)	(110)	(111)	(100)	

[a]See Table 3 for definition of abbreviations. Ratios relative to HA-X are given below in parentheses.

[b]Standard error of breed-cross means.

[c,d]Means within a row with different superscripts differ ($P < .05$).

equivalent of 88 Mcal (16%) more creep feed (FME_{calf}) than those in this trial, and thus averaged slightly higher in $\%ME_{calf}$.

Efficiency Estimates. Mean efficiency values are given by breed cross in both absolute and relative terms in Table 9. In general, the two *Bos indicus-X* groups were more efficient than the *Bos taurus-X* groups.

Calf efficiency (PEFF), measured as GAIN over calf ME intake from milk and creep feed, averaged 15% greater ($P < .01$) for the Bm-X and Sw-X than for the Pz-X and HA-X crosses. However, CEFF must be interpreted cautiously, because its calculation assumed that calf milk consumption was measured with equal accuracy for the different F_1 dam groups and that breed-cross groups converted milk to gain with equal efficiency. The estimates of milk production, if biased for any reason, could under- or overestimate actual calf milk intake and thus bias the estimates of PEFF.

Cow efficiency (CEFF) was measured as calf GAIN over cow ME feed intake independent of estimated milk production, but it omitted calf intake of creep. Thus CEFF was only 7.5% higher for the two *Bos indicus-X* groups than for the two *Bos taurus-X* groups ($P < .10$), partly because their lower creep intake was ignored. Relative to HA-X, cow efficiency was 3.6% lower for Pz-X but only higher by 3.9% for the Bm-X and by 7.3% for the Sw-X groups.

The final and most meaningful evaluation of efficiency was in terms of calf GAIN over ME in feed consumed by both cow and calf (TEFF, g/Mcal), independent of any measures of milk production. It showed a distinct 11% advantage of the two *Bos indicus-X* groups over their *Bos taurus-X* counterparts ($P < .05$, Table 4). Differences between HA-X and Pz-X, or between Bm-X and Sw-X, were negligible.

The means presented here for TEFF are lower than those found by Cundiff et al. (1983) for the Cycle II-2 F_1 crosses, judging by the HA-X, which were included in both experiments (31.6 vs 35.8 g/Mcal). The present DME_{zero} estimate was similar to that found in the earlier experiment (24.2 vs 24.9 Mcal/cow), but the daily calf creep feed consumption was lower for the same time-constant feeding period (5.27 vs 5.71 Mcal/calf). The primary cause of the lower total efficiency for HA-X crosses in the present experiment was lower calf gains (117 vs 138 kg).

Discussion

The 11% advantage of the two *Bos indicus* crosses over the two *Bos taurus* crosses in biological efficiency for this 126-d lactation phase of the annual production cycle is of potential economic importance. However, some aspects of these results warrant further consideration.

In the similar trial reported by Cundiff et al. (1983) using F_1-cross cows from Cycle II of the GPE program, the breed groups with the lowest cow feed input (i.e., HA-X and Red Poll-X) were superior in total efficiency, in part because feed for the cow made up 80 to 85% of the total feed input. The 10% higher total efficiency for the HA-X group in their earlier study than in the present experiment is explained by the similar cow feed intakes but 18% higher calf gains.

Identifiable differences between the Cycle II-2 and Cycle III-2 trials were older cow ages (7 to 9 vs 11 to 12 yr), Simmental vs Charolais sires of calves, 138-d vs 126-d lactation period, and 40 kg lighter cows in the Cycle II experiment. The HA-X cows used in the two trials were produced from the same H and A dams, except that more of the Cycle III foundation females were produced at the RLHUSMARC (Gregory et al., 1979a). Estimated average daily milk yield was 7% higher in Cycle II-2 HA-X (6.86 vs 6.37 kg/d) and DME_{zero} was 3% higher (24.86 vs 24.15 Mcal ME/cow/d). Calf creep consumption was also higher in the study by Cundiff et al. (1983).

The difference in age of cows would seem the most plausible explanation of the higher total efficiency for the HA-X group in the Cycle II-2 experiment. Older and fatter HA-X cows in Cycle III-2 would contribute to a poorer maternal environment for calf growth. The effect of older cows in Cycle III-2 also could have favored the *Bos indicus-X* cows. Cartwright (1980) and Turner (1980) have stated in reviews that Zebu crosses seem to have superior longevity in maternal performance relative to European breed crosses. The Bm-X and Sw-X groups in this study may have benefited from such an interaction because the cows used would be considered beyond mature ages for most *Bos taurus* breeds.

Any efficiency advantage of breed groups from size divergence between sire and dam would most benefit the Sw-X and HA-X cows, from raising larger calves with lower cow maintenance inputs. The TEFF of Bm-X, and to a lesser extent that of Pz-X, cows was handicapped in this respect.

Another advantage of the *Bos indicus*-cross groups is a higher level of heterosis. Cundiff (1970) and Long (1980) documented two to three times higher levels of heterosis in *Bos indicus* × *Bos taurus* than in *Bos taurus* × *Bos taurus* crosses (both individual and maternal). The Bm-X and Sw-X groups may have benefited from greater heterosis in milk production, calf growth, efficiency of feed utilization, and longevity of production. Differences in longevity would be particularly relevant, because of the relatively older cows involved in this study.

The low ranking of the Pz-X group may be related to the Pz breed history in Austria, where it has been selected as a dual-purpose breed under nearly optimal conditions. Any effects of heat stress from the summer environment in south central Nebraska where these data were collected could have been a disadvantage for the Pz-X cows, particularly compared to the more heat-tolerant *Bos indicus* crosses.

Implications

Results from the present experiment indicate substantial advantages of *Bos indicus-Bos taurus* over *Bos taurus-Bos taurus* crossbred cows for these particular sources of germ plasm, for components of input, output, and output/input efficiency during an 18-wk lactation portion of the annual production cycle. Further work is needed to extend the comparison of efficiency to the entire production cycle and to herd structure for different breeding systems. Such work would help to define the optimal role of *Bos indicus* germ plasm for breeding programs in the temperate regions of North America.

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